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LITTLE CORNWALLIS ISLAND
ICE CUTTING TRIALS

TP 4016E

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ICE CUTTING TRIALS

by

Acres Consulting Services Limited
Calgary, Alberta

February 1983

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17. Abstract

This report describes a program carried out at Little Cornwallis Island in November 1982 to investigate the effectiveness of ice cutting techniques and explosives in assisting the M.V. Arctic to berth on her last voyage for the season. It was anticipated that large pieces of ice, broken by the vessel while berthing, would become jammed between the vessel and the dock thereby preventing the vessel from contacting the dock. In order to have the vessel break the ice into small pieces that would be flushed away by the propeller and bubbler, the ice was slotted with chain saws over the berthing area. Various cutting patterns were used over a distance of 185 m and explosives were tested over a distance of 70 m along the line of approach of the vessel. The effectiveness of the cutting patterns could not be tested because of the nonarrival of the vessel. However, cutting proved to be fairly fast and efficient. Average cutting rates 1.3 m/min were achieved over the test period and approximately 60 m of ice about 30 cm deep was cut for each litre of fuel consumed. The explosives were very effective in breaking the ice and if they could be used close to the dock would provide a fast means of breaking up the ice cover. A thick zone of ice, formed due to flooding at high tide, was found to exist near the dock and it was concluded that this ice would present the greatest problem for berthing.

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17 Résumé

Ce rapport rend compte des travaux réalisés en novembre 1982 à Little Cornwallis Island dans le but de déterminer l'efficacité d'une méthode de déglaçage combinant le découpage de la glace et le sautage d'explosifs, technique envisagée pour permettre au cargo brise-glace Arctic de se ranger le long du quai lorsque vient la fin de la saison de navigation. Il avait été déterminé que, au moment où ce navire accosterait, il serait gêné par les gros blocs de glace pris entre le quai et le navire. Pour que la glace puisse être fracturée en morceaux de moindre grosseur susceptibles d'être emportés par l'hélice du navire et le système à bulles d'air, elle avait été entaillée à l'aide de tronçonneuses, là où le navire devait se placer. Diverses découpes ont été exécutées sur une distance de 185 m et on a fait sauter des explosifs sur une distance de 70 m, le long du trajet que devrait emprunter le navire. L'utilité de cette méthode n'a pu être vérifiée car le navire n'est pas venu à l'île. Néanmoins, le découpage s'est révélé d'exécution assez rapide et économique. La vitesse de coupe a été de 1,3 m/min. en moyenne et approximativement 60 m de glace ayant queque 30 cm d'épaisseur ont pu être entaillés pour chaque litre de carburant consommé. Le sautage d'explosifs s'est révélé très efficace et cette méthode pourrait accélérer le déglaçage s'il y avait moyen de l'utiliser à proximité du quai. Une épaisse zone glacée, formée par la marée montante, a été découverte près du dock, et c'est cette zone surtout qui risque d'entraver le rangement du navire le long du quai.

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Project Organization

This project was funded by the Transportation Development Centre (TDC) and was undertaken for TDC and Canarctic Shipping Limited. The field program was carried out by Acres with assistance from Arctic Bay personnel under the supervision of Mr. G. Williams of Arctic Bay.

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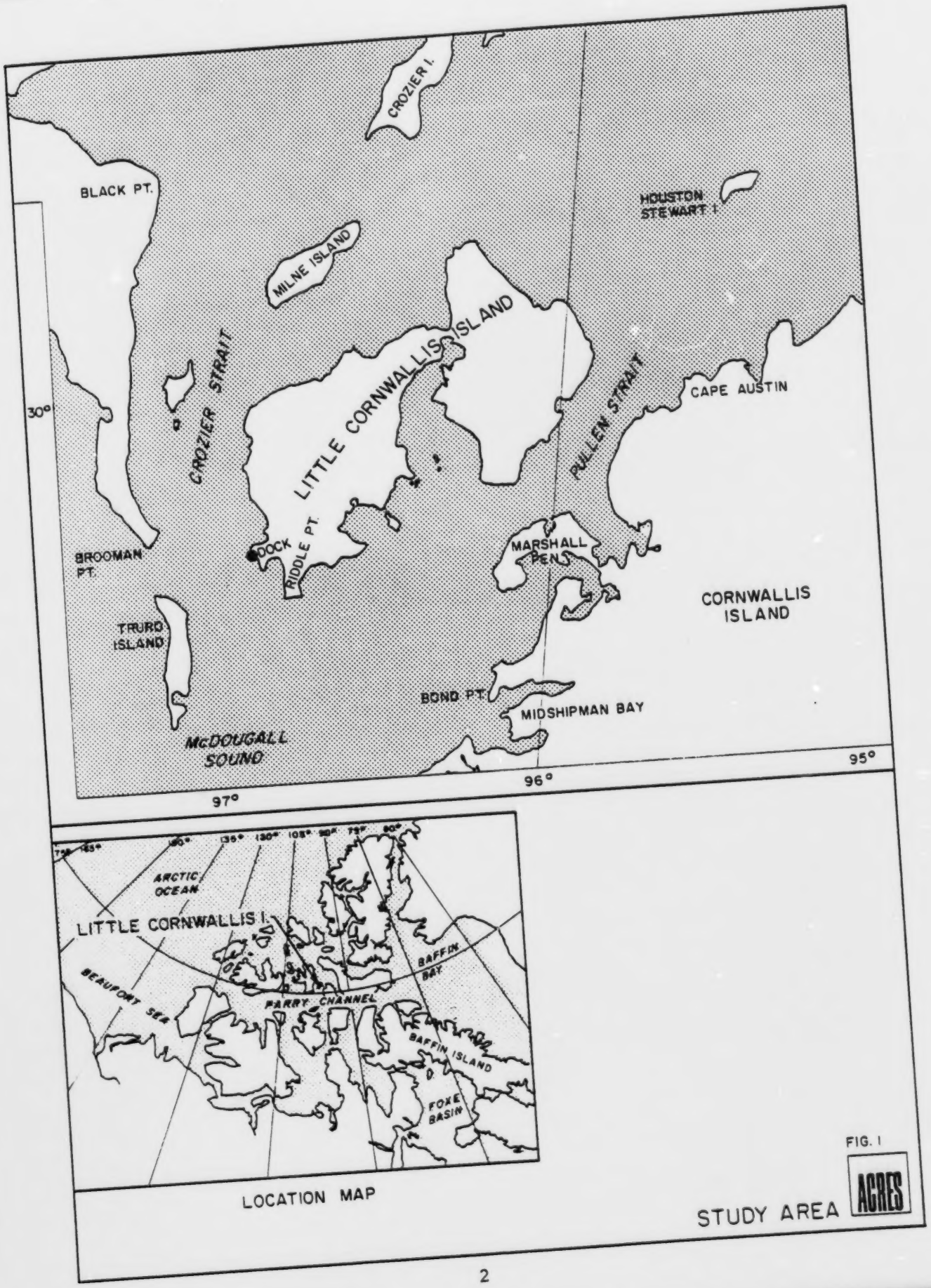
1. INTRODUCTION

Based on experience from previous years at Nanisivik, it was anticipated that during the last voyage of the 1982 shipping season to Little Cornwallis Island, N.W.T. (Figure 1), the M.V. Arctic would have difficulty in berthing immediately adjacent to the dock because large pieces of ice broken by the vessel would become jammed between the vessel and dock. These pieces would be too big to be washed away by the vessel propeller and bubbler system. It was thus considered necessary to undertake methods of preventing this problem and thereby ensure that the vessel would be able to dock as required.

Accordingly the Transportation Development Centre contracted Acres Consulting Services Limited to carry out a field program in which a number of possible remedial measures would be investigated; however, the principal measure would be the mechanical cutting of the ice. Prior to conducting the field work, a literature search was carried out in an attempt to identify the effects of the cutting of the ice on the subsequent size of the pieces broken by a vessel. No relevant published articles were found; however, discussions with Canarctic Shipping Limited, the operator of the M.V. Arctic, revealed that some model testing had been done by Wartsila in Finland on the effects of certain cutting patterns on ice breaking. Although it appears that this work was primarily concerned with wave effects on the ice, it was found that a herringbone pattern resulted in the ice being broken into smaller pieces by a traversing ship than would be the case in an undisturbed ice sheet. Following this information, the test plan for the present program involved two areas with different herringbone patterns as described in Section 2.

Some testing with explosives was also carried out in an area well removed from the dock, but in the line of vessel approach, to determine their effect on breaking the ice.

Unfortunately, the effectiveness of these measures could not be determined because the vessel did not reach the site because of heavy ice conditions in Lancaster Sound. Some valuable information on the practical aspects of the methods was obtained, however, and results pertaining to this are presented in this report. Recommendations are also made for further consideration of the problem presented by ice to a vessel berthing at the dock.


CROZIER I.
BLACK PT.
HOUSTON STEWART I.
MILNE ISLAND
CROZIER STRAIT
LITTLE CORNWALLIS ISLAND
PULLEN STRAIT
CAPE AUSTIN
30°
DOCK
RIDDLE PT.
MARSHALL PEN
BROOMAN PT.
CORNWALLIS ISLAND
TRURO ISLAND
BOND PT.
MIDSHIPMAN BAY
McDOUGALL SOUND
95°
96°
97°
ARCTIC OCEAN
LITTLE CORNWALLIS I.
BAFFIN BAY
BEAUFORT SEA
PARRY CHANNEL
BAFFIN ISLAND
FOXE BASIN
LOCATION MAP
STUDY AREA
FIG. 1
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2. TEST PROGRAM DESCRIPTION

2.1 General

A plan of the test area with the cutting patterns and explosives test section is shown in Figure 2. With the M.V. Arctic positioned for loading Hold 4, the bow of the vessel extends 76 m beyond the centerline of the forward dock cell (the north end of the dock) and the stern 47 m beyond the centerline of the after cell (at the south end). The total length of the test area was 235 m which includes four cutting zones and one explosives zone. This test area was longer than that set out in the test plan because the work proceeded faster than anticipated and time permitted extra cutting. The width of the test area was 28 m from the forward limit to a point 90 m to the rear; it then widened at a 10-deg angle to allow for the approach of the vessel. In Zones 1, 2 and 3, the perpendicular spacing of the lines was 1.5 m; in Zone 4 the spacing was 5 m. The explosives test area was to the south of the cutting areas and in line with a vessel approach of 10 deg.

The areas were laid out by simply measuring off the appropriate distances and placing marks with spray paint where cuts were to be made. For each cut, a rope was then stretched between two poles placed in the ice at end points of the line to be cut. The cutting then followed this line. This method was used over the entire test area. The test area was marked along the outer limit by radar reflectors.

2.2 Ice Thickness Measurements

Before cutting was started, several isolated ice thickness measurements were made to determine the appropriate depth of cut. This was done to prevent the saws from cutting completely through the ice to avoid water in the slots and freezeback of the cut. Measurements were made by inserting a metal rod with a 90-deg elbow in the slot made by the chain saw and then measuring the length of the portion in the ice.

More detailed thickness measurements were made after the cutting had been completed. Profiles were obtained for a distance of approximately 25 m from each of the dock cells.

2.3 Explosives Testing

An area on the approach line of the vessel and to the south of the dock for about 100 m was used to test a quantity of explosives (see Figure 2). The ice in the test area was approximately 0.6 m thick and based on this thickness, the

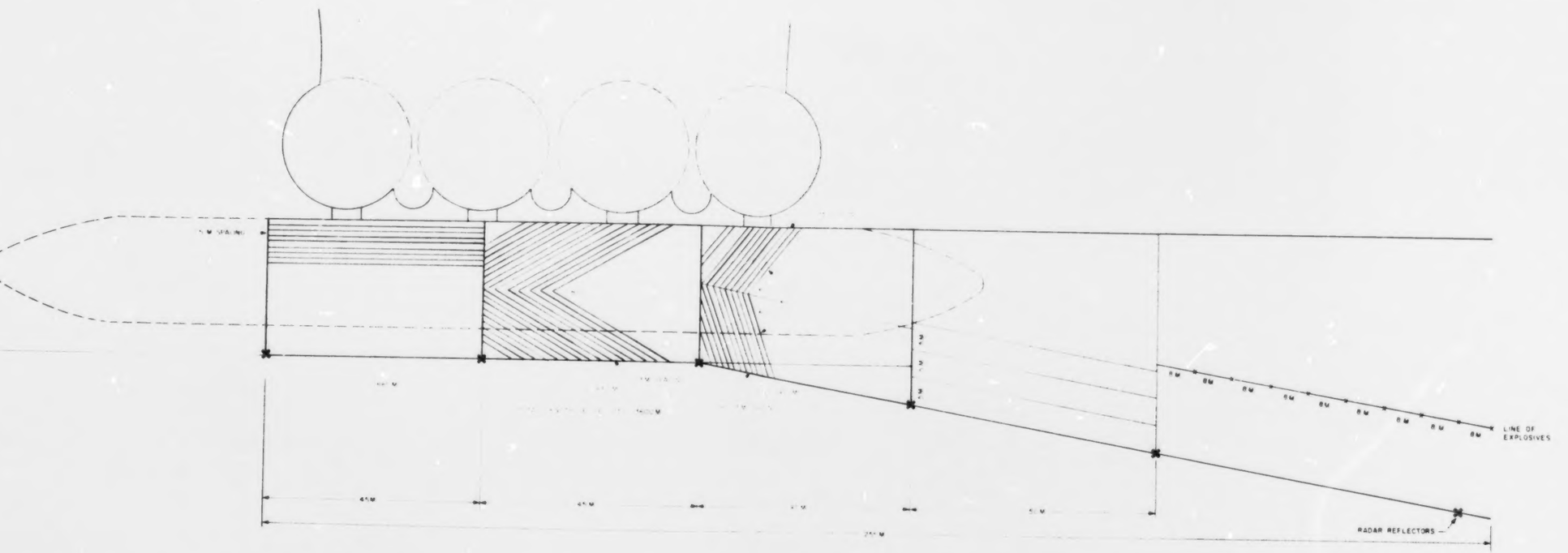


FIG. 2

ICE CUTTING TRIALS LITTLE CORNWALLIS ISLAND – TEST PLAN AREA

individual charge weight was selected at 2.5 kg. Nine such charges were set in 0.20-m holes drilled in the ice at a spacing of 8 m. The total charge weight was approximately 25 kg and the total length of the test area was 70 m. Each charge was placed at a distance of approximately 0.20 m below the ice cover. The charge weights, spacing and placement below the ice were determined from published reports of previous tests in ice. The explosive was Cilgel B which is manufactured by C.I.L. Industries Limited. Each stick of explosive was approximately 0.20 m long, 2.5 cm in diameter and weighed 125 g. Approximately 20 such sticks were taped together to form each charge which was then tied with B-line detonating cord. The cord was tied around a 5-cm by 5-cm wooden stick and the charge suspended through the hole drilled in the ice. The stick lying across the hole ensured that the charge remained at the desired depth. The hole was then covered in with snow and slush to maximize the charge effect. All the charges were connected to the detonating cord which was in turn connected to a fuse. The charges were then fired simultaneously.

3. RESULTS OF TEST PROGRAM

Because the M.V. Arctic did not arrive at Little Cornwallis Island, it was not possible to determine the effectiveness of the various test patterns on berthing. This section of the report is limited, therefore, to a presentation of the performance data obtained during the cutting procedures, the results of the explosives test and data on ice conditions in the test area.

3.1 Cutting Performance Data

The total length of ice cuts made was approximately 3,600 m. This cutting was completed in less than 3 working days and the total cutting time was estimated to be 16 hours. Over this time, on average 3 saws were operating so that the total cutting time was 48 man-hours. This results in an average cutting rate of approximately 1.3 m/min. Some random measurements of short-term cutting rates were made; these were as high as 4 m in 1 min. Plate 1 shows the 120-deg cutting pattern and Plate 2 a portion of the 60-deg pattern used in the tests.

Fuel consumption for the entire cutting was approximately 60 L (13 imp gal) so that the cutting distance per unit consumption was 60 m/L or about 275 m/gal.

The saws were John Deere 80-EV with 60-cm cutting bar. Regular log cutting chains were used in the tests.

Attempts were made to maintain a regular slot depth throughout the cut. During the first day, cutting depths were as much as 35 to 40 cm. It was found, however, that in some cases water seeped into the slots, and the ice had to be cut again at a smaller depth. Following this experience, cuts were maintained at depths of less than 30 cm. It was found, however, that after 2 or 3 days, water still tended to seep into the cuts so that some freezeback occurred. Random checking indicated that the cuts had refrozen to a depth of 20 to 25 cm in that time. It is therefore important to minimize the amount of time between ice cutting and vessel arrival.

3.2 Explosives Test Data

The ice in the explosives test area was approximately 0.6 m thick and based on this thickness, the individual charge weight was selected at 2.5 kg and the placement below the ice sheet at 0.20 m. The 9 craters resulting from the explosion had diameters ranging from 2.5 m to 6.1 m with a mean diameter of 5.2 m. Because the charges were placed at a

PLATE 1 - 120° cutting pattern

PLATE 2 - 60° cutting pattern (seaward portion)

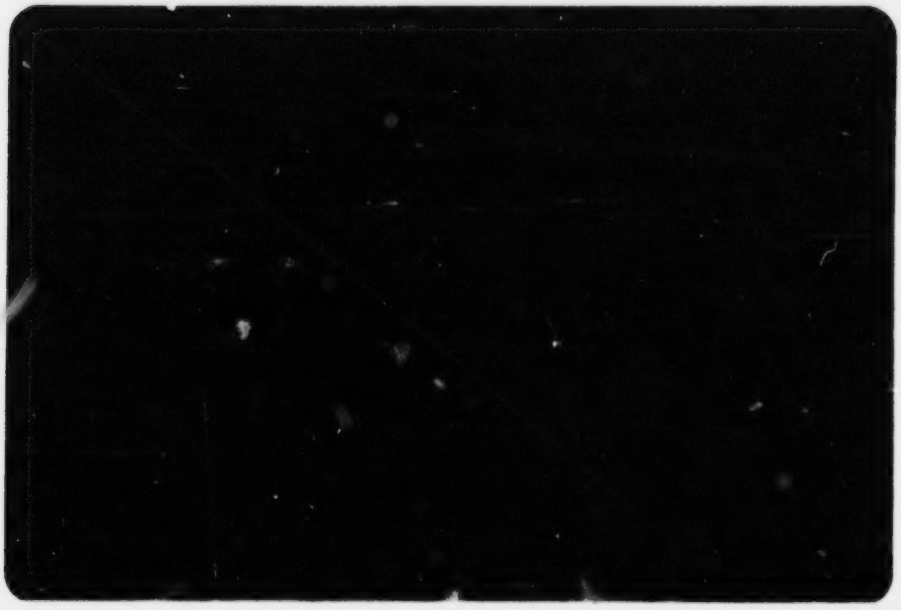
spacing of 8 m, no two of the craters were interconnected. The distances between the craters ranged from 2 m to 4.1 m. The ice pieces in the crater were generally only a few centimetres across; some larger pieces in the order of 20 to 30 cm were tossed out of the crater and onto the undisturbed ice sheet. In general, the explosives were very effective in breaking the ice cover into very small pieces. Plates 3 and 4 show typical results with the explosives.

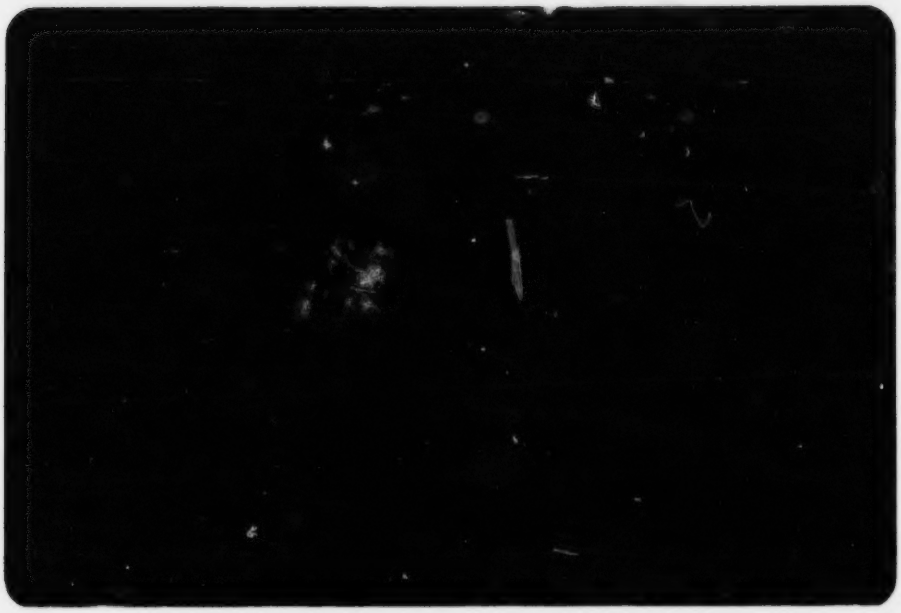
3.3 Ice Thickness Data

The ice surface in the test area was somewhat rough due to the refreezing following the transit of the previous ship into the dock several weeks prior to the test program. A general view of the ice in the berthing area and an overall view of the dock are shown on Plates 5 and 6. Blocks of ice were scattered over the area and were frozen into the new ice cover. Snow cover was generally light being usually less than 10 cm; however, in some sections snow thicknesses of up to 50 cm were measured. Ice thickness profiles along a line from each of the dock cells are shown in Figure 3. The important feature is the thicker ice adjacent to the dock. This ice is separated by cracks from the main ice sheet and hinges and rotates about this ice cover and the dock as the tide rises and falls. On a high tide, the outer edge of the ice rises with the main ice cover while the inner edge may be constrained at the dock. The surface then becomes flooded with a subsequent accelerated ice growth at the top (see Plate 7).

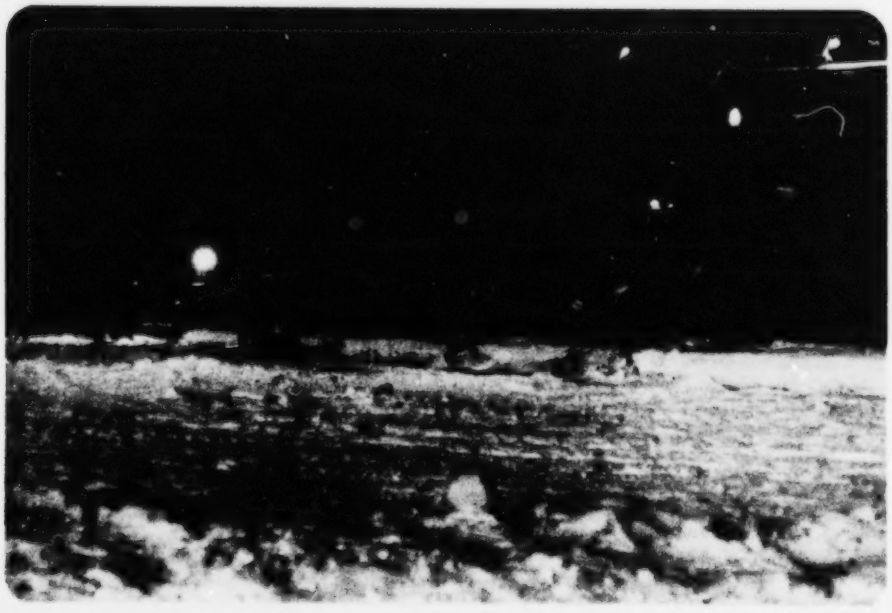
The ice collar or "bustle" which forms early due to the tides, was evident on all cells except the extreme northern cell. There the bustle had fallen away from the cell, the cell joint impression still being evident on the vertical face of the ice (see Plate 8). The sewage discharge is at this end of the dock, so presumably the cell was being heated slightly by warmer water in that area. On the other cells, this bustle was 1.3 m wide at the center of the cell and 1.3 to 1.4 m deep (see Plate 9). As the tide changes, the ice moves against this bustle and sometimes breaks which results in rough, broken ice adjacent to the bustle and immediately below the dock fender (see Plate 10).

Because this thick ice adjacent to the dock extended for a distance of up to 4 m, it was expected that it would have caused significant problems for the M.V. Arctic during berthing. Because this ice was cracked and became flooded during high tide, it would have been futile to cut it several days prior to vessel arrival. The plan was therefore to cut it only a few hours before arrival and following a high tide. This was not done, of course, because of the nonarrival of the vessel.





PLATES 3 and 4 - Typical results with explosives



PLATES 5 and 6 - Ice in the berthing area and overall view of dock

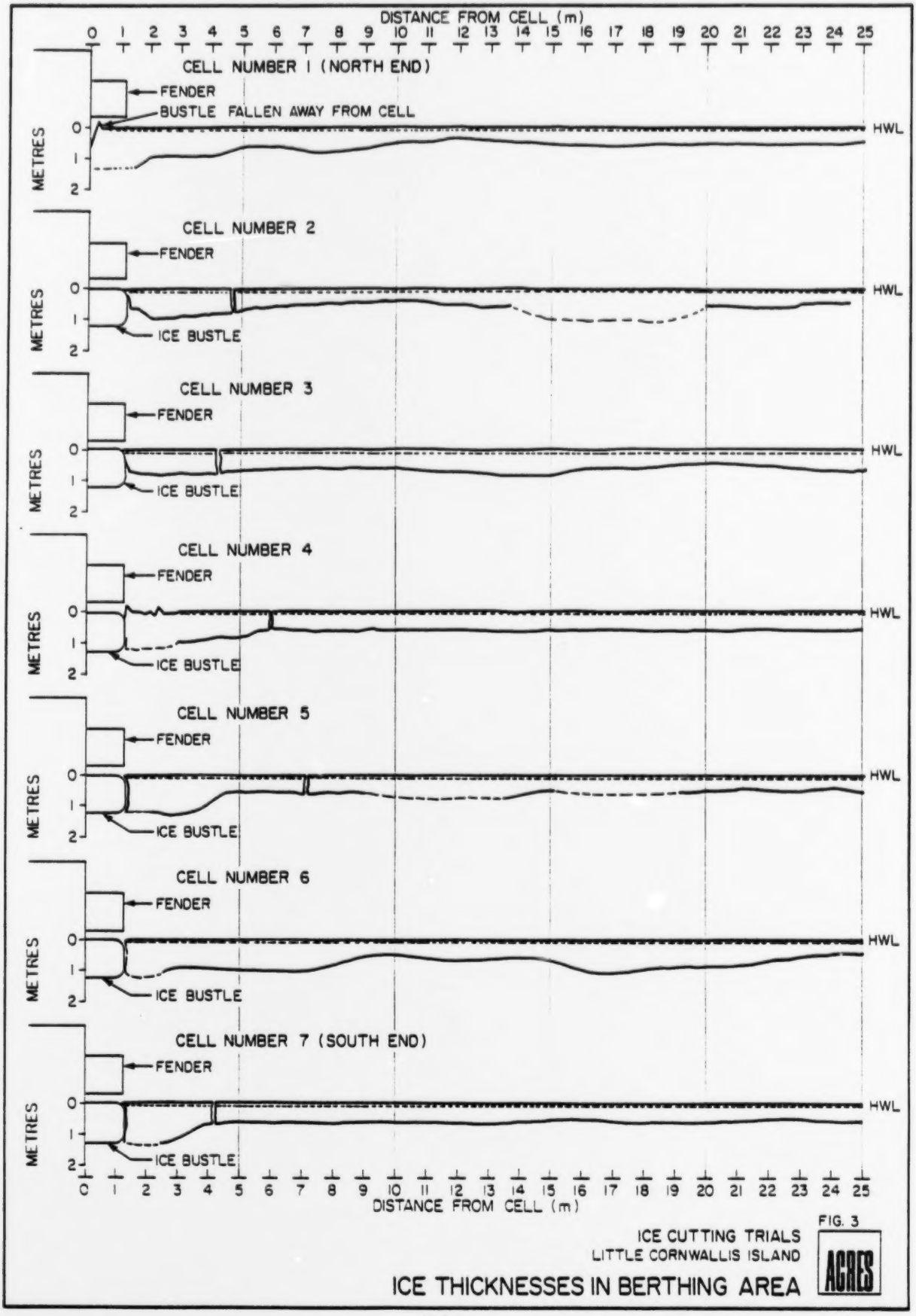


FIG. 3

ICE CUTTING TRIALS
LITTLE CORNWALLIS ISLAND

ICE THICKNESSES IN BERTHING AREA

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PLATE 7 - Hinge of ice near dock on rising tide

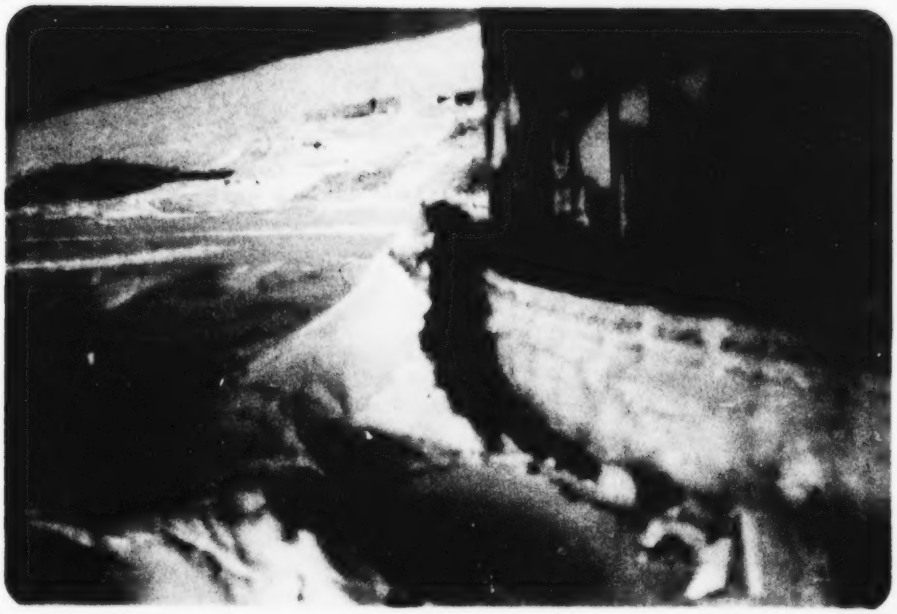

PLATE 8 - Ice features at cell at north end of dock

PLATE 9 - Ice bustle at dock face

PLATE 10 - Ice pileup near bustle

Ice thickness data, as determined from measurements made by the Atmosphere Environment Service on Resolute Bay, are shown in Figure 4 for the period up to November 19, 1982, and also for 1955 to 1972. It is seen that 1982 thicknesses are a little lower than the mean thickness by up to approximately 10 percent; however, they are well within the standard deviation limits of the 1955 to 1972 records. It is expected that historical ice conditions at Resolute Bay and Little Cornwallis Island are similar.

3.4 Weather Conditions

During the period of the tests, November 5 to 13, the weather was clear and cold with low winds. Weather data collected by the observer at Little Cornwallis Island showed that the temperature during the period ranged from -31°C to -39°C and the winds were primarily from the north with speeds ranging from 0 to 22 km/hr.

A comparison of weather data from Resolute Bay meteorological station for the period September 1 to November 16, 1982, with average records indicates that this fall was somewhat colder than normal, although the temperature was above normal for the periods October 5 to 12 and October 26 to November 2 (see Figure 5). During the test period, the average temperature was 5 deg to 9 deg below normal.

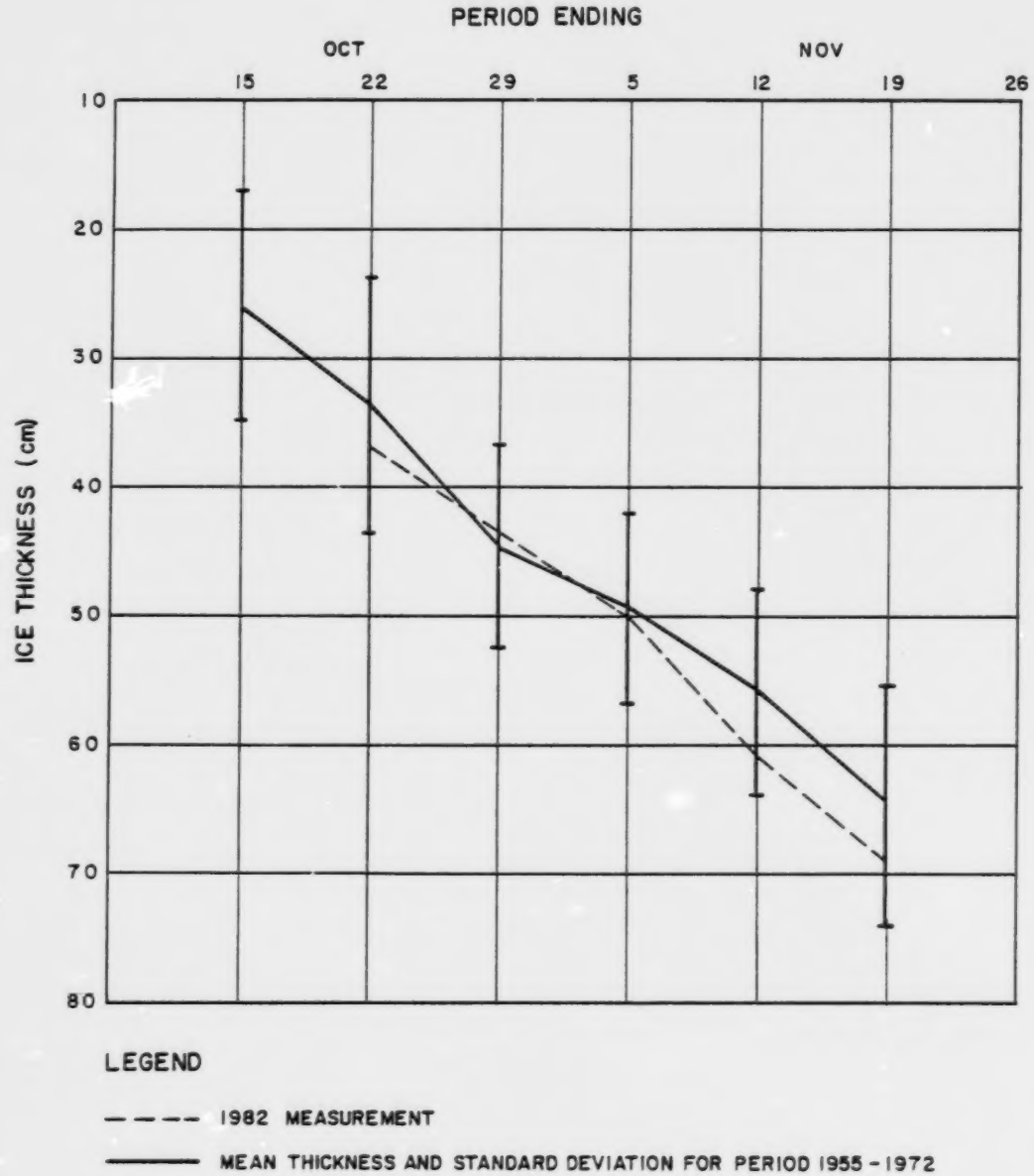

FIG. 4

ICE THICKNESS DATA FOR RESOLUTE FOR PERIOD TO NOV. 19

AGRES

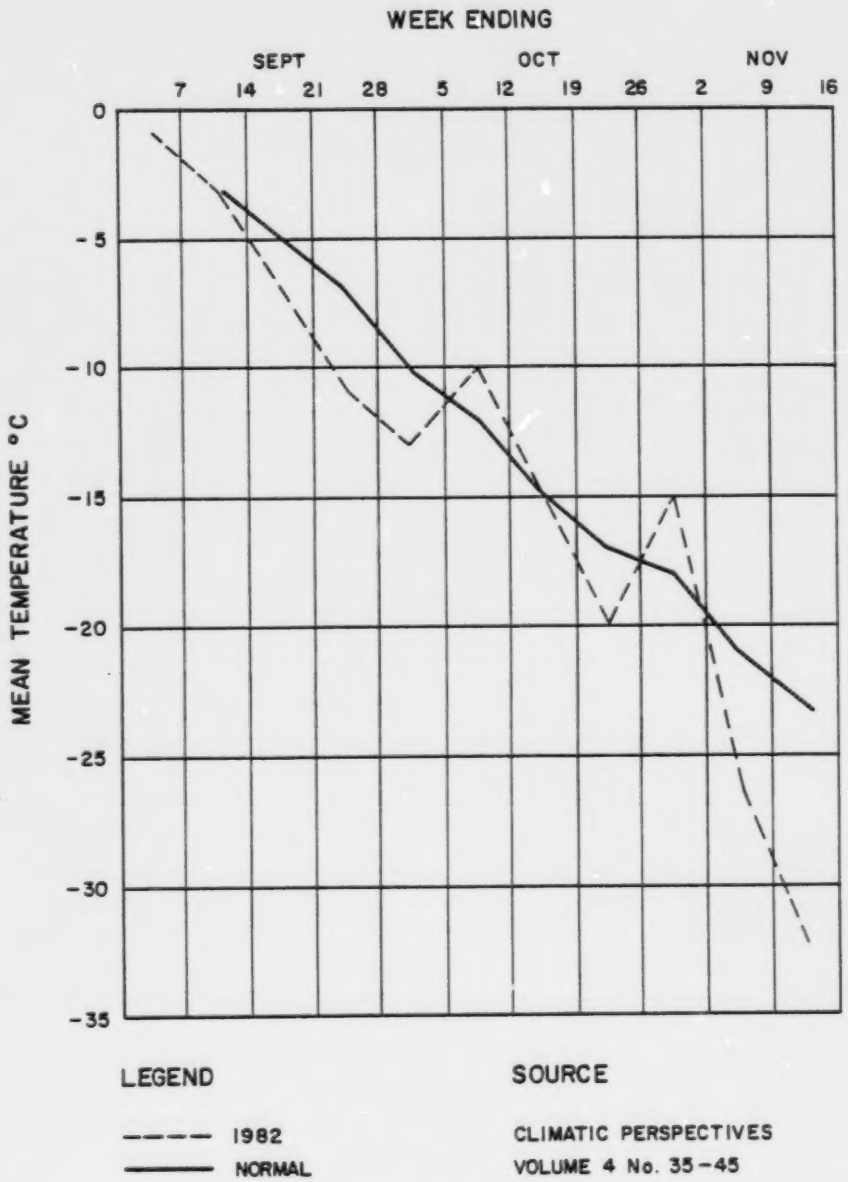

FIG. 5

TEMPERATURE DATA FOR RESOLUTE FOR PERIOD SEPT. 1- NOV. 16

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4. CONCLUSIONS AND RECOMMENDATIONS

Because of the nonarrival of the M.V. Arctic, no conclusion can be drawn with regard to the effectiveness of the test program. However, some comments can be made with regard to the practicality of the methods used and the logistical and economic feasibility.

The method of cutting the ice with saws proceeded faster than had been anticipated during the planning of the program, and the tests showed that a considerable area of ice can be cut in a relatively short time. Mechanical cutting also proved to be energy efficient with about 60 m of ice being cut for each litre of fuel used. This efficiency depends on the volume of ice cut which is determined by the depth of the cut. If shallower cuts can be tolerated, corresponding savings in energy and time would result.

If the depth of the cuts has to be close to the ice thickness in order to be effective, then the cuts cannot be made very long in advance of the vessel arrival since water would fill the cuts and freeze. It is thus necessary to determine the minimum depth of cut that will be effective in producing manageable pieces of ice.

These comments apply more to the uniform ice cover than to the ice adjacent to the dock which grows at an accelerated rate because of the tidal action. In this zone, the ice can be cut only immediately prior to vessel arrival to present freezeback of the cuts.

It is estimated that using chain saws and local labor, the annual costs associated with cutting ice in this manner to enable a vessel to dock would be less than $10,000. Therefore from economic point of view, this method is attractive.

Some thought should be given to improving the method of cutting the ice possibly by mounting the cutting tool on a movable vehicle. In the Soviet Union, a circular blade fitted to an Archimedean Screw Tractor has been used to cut ice on rivers and thereby advance the breakup. Such a vehicle could be useful for the present application. A chain saw could also be mounted on a platform which moves over the ice. It is possible however that neither of these could be used in the ice immediately adjacent to the dock, this area actually being the most critical. Here manual operation with chain saws or a ditching machine could be used. (More detailed consideration is given to the general problem of an

exaggerated ice growth near the dock in a recent report prepared by Acres for the Transportation Development Centre).*

The tests with explosives indicated that they would be an effective and simple way of breaking up the ice in the berthing area. If they could be used close to the dock they would also be effective in the thicker ice there. With proper procedures and protection measures, it is quite possible that explosives could be used close to the dock. This matter needs further investigation. In general, a grid of charges could be laid in the berthing area with spacings equal to the diameter of the predicted craters. In this way, all the ice in the area would be broken. Five lines of 20 charges each would be sufficient for this; the total charge weight would then be approximately 250 kg. The holes could be drilled and the charges laid out in 1 or 2 days using 4 men.

Because this project did not determine the effectiveness of the cutting patterns, it is recommended that a physical modeling study be undertaken. Such a scaled study should provide results indicative of those that would be experienced in full scale. Tests could be conducted in synthetic ice for the sake of expediency and economy, and any number and types of cutting patterns could be tested. Tests could also be conducted with greater thicknesses of ice immediately adjacent to the dock to simulate the buildup of ice due to tidal effects. The costs for such a program would, of course, vary with the complexity and number of tests but should be in the order of $20,000 to $30,000.

It is also recommended that ice thickness measurements be made near the dock toward the end of winter to determine the extent and thickness of the ice hinge. If an earlier startup to the navigation season were anticipated, consideration would have to be given to the extent of this increased ice growth near the dock. Forces resulting from the action of the ice hinge are also of interest for dock design. Comparison may also be made with measurements by the National Research Council on ice conditions around the Nanisivik dock.

Consideration should also be given to studying this increased ice buildup near the dock as a function of the dock design and the tidal range. It is possible that the hinging effect may be created only within limited tidal ranges; it may or may not exist in areas of very large tidal ranges. This effect would be amenable to physical modeling and possibly analytical treatment.

*Acres, 1982 "Ice Control for Arctic Ports and Harbours". Report prepared for Transportation Development Centre, January 1983.